The Flood Event of 30 June – 18 July, 2002 in the Texas Hill Country

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Abstract.

Canyon Dam experienced the worst flood in its 40-year history during the summer of 2002. A low-pressure system migrated west from Florida to Texas in late June. This system became nearly stationary over South Central Texas pulling tropical moisture inland from the Gulf of Mexico causing heavy rainfall. Storms repeatedly dumped rain on an area from southwest of San Antonio to the northern Hill Country causing tremendous rainfall accumulations. Some areas of the Guadalupe River Basin above Canyon Lake received more than 50 inches of rain during a seven-day period. The average rainfall over the Canyon Lake watershed was 22 inches, resulting in approximately 700,000 acre-feet of runoff into the reservoir. This volume of water was enough to fill the flood control pool twice. The water level rose over 40 feet, and peaked almost 7.5 feet above the spillway crest. The maximum discharge over the spillway was about 66,800 cfs, while the channel capacity of the Guadalupe River at New Braunfels, downstream of Canyon Dam is 12,000 cfs. The high spillway flow caused millions of dollars in damages below Canyon Dam.

Introduction.

July is normally one of the driest months in Texas, but July 2002 was not normal. By the end of the day on 1 July, San Antonio had already experienced its wettest July ever and the second rainiest month and day on record. Scattered rains that began as early as 27 June in the Hill Country spread to all of South Central Texas. Widespread and disastrous flooding developed on four major river basins and two reservoirs. Numerous high water rescues took place along the flooding rivers. People and pets were rescued from camps, cars, homes, and vacation resorts across the flooded areas during the first week of July. Homes, businesses, roads, and bridges were destroyed in the floodwaters. Evacuations were widespread in several counties. Extensive damages to crops, livestock, and agricultural equipment occurred on the Medina, San Antonio, Nueces, Blanco, San Marcos, and Guadalupe Rivers. Canyon and Medina reservoirs spilled over the emergency spillways. Officials estimated damage to 48,000 homes and as much as 1 billion dollars in damages. Twenty counties were declared disaster areas. Seven fatalities were attributed to the flooding.

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Description of the Drainage Basin. The Guadalupe River Basin is relatively long and narrow, with an over-all length of approximately 237 miles and a maximum width of about 50 miles, and a drainage area of about 6,032 square miles. From its source, the Guadalupe River flows in an easterly direction for a distance of about 184 miles to the Balcones Escarpment near the city of New Braunfels. Thence turning southeasterly, the river flows for about 280 miles to San Antonio Bay, an estuary of the Gulf of Mexico. The elevation of the basin increases from sea level at the mouth to an elevation of about 2,400 feet National Geodetic Vertical Datum (NGVD) in the extreme headwater area.

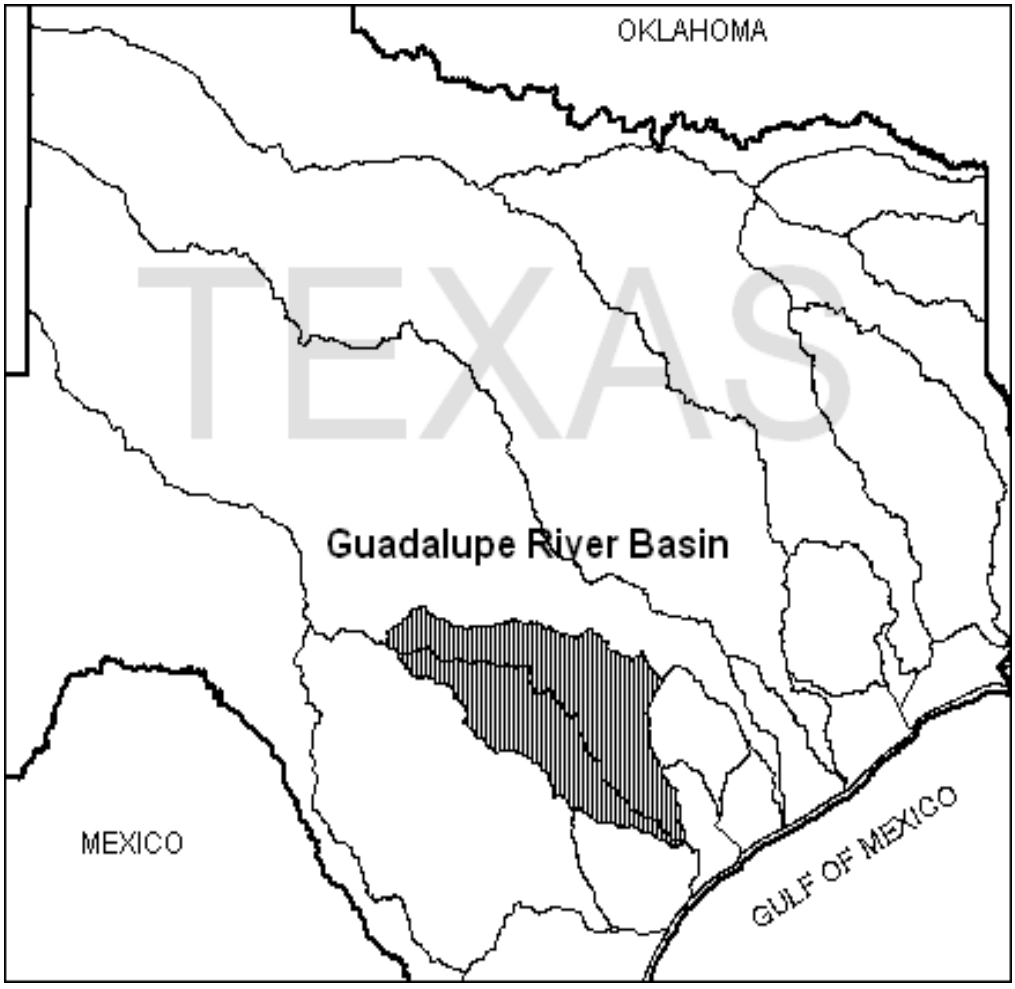

Figure 1. Map of River Basins in the State of Texas.

Location. Canyon Dam is located on the Guadalupe River at river mile 303.0, about 12 miles northwest of New Braunfels, Texas, and about 38 miles north-northeast of San Antonio, Texas. The dam is located in north central Comal County, on the eastern edge of the Edwards Plateau just west of the Balcones Escarpment. Canyon Dam is the only flood control structure in the Guadalupe River Basin. The drainage area of Canyon Lake is 1,425 square miles and stretches from Comal County across Kendall and Kerr Counties.

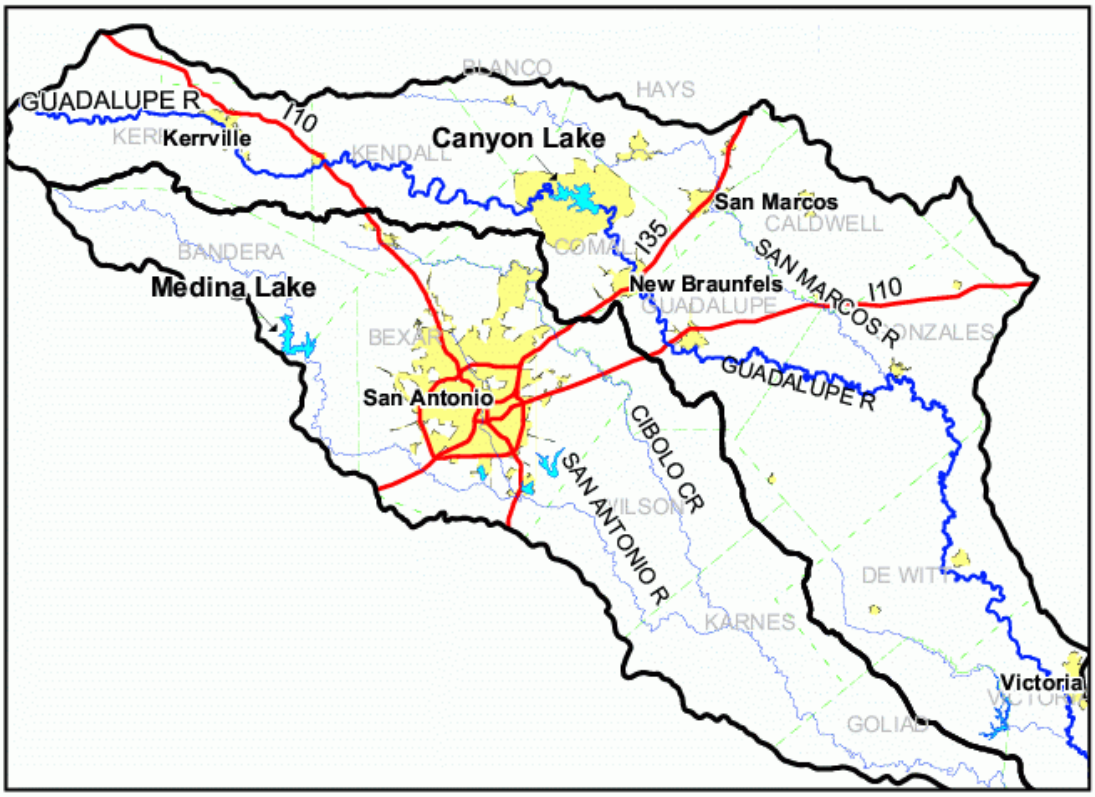

Figure 2. Map of the Guadalupe River Basin.

Topography. In the Edwards Plateau above New Braunfels is a region of rugged hills and narrow valleys, which is commonly known as the "Texas Hill Country." On the eastern edge, the plateau is accentuated by steep hills and limestone bluffs that form the Balcones Escarpment, the boundary between the plateau area and the coastal plains. In the plateau area, the Guadalupe River is deeply entrenched, flowing for the greater part of its course in narrow canyons 200 to 300 feet deep. The river follows a winding course throughout its length, which is about twice the length of the valley axis.

The area in the immediate vicinity of Canyon Lake is very rugged, characterized by numerous elongated hills, which are formed by erosional outcrops of massive limestone underlying the area. The hills average about 250 feet in height and have very steep and generally barren slopes. The hills crests are relatively flat except for occasional shallow, intermediate, erosional divides.

Precipitation. The mean annual precipitation over the Guadalupe River Basin is about 34 inches, which varies from 36 inches near the mouth to about 29 inches in the headwaters. The mean annual precipitation over the Canyon Lake watershed is about 30 inches. The Hill County is renowned to have the most intense rainfall in the world. D'Hanis, Texas recorded 22.0 inches in 2 hours, 45 minutes on 31 May 1935, also Thrall, Texas recorded 36.40 inches in 18 hours on 9 September 1921.

U.S.G.S. Stream Gages. The U.S. Geological Survey, in cooperation with the Corps of Engineers, National Weather Service, and Guadalupe-Blanco River Authority, maintain a network of weather stations and stream gages in the Guadalupe River Basin. There are seven U.S.G.S. stream gages upstream of Canyon Dam. Of the seven upstream gages, four are on the main stem of the Guadalupe River and are used to forecast inflows. When regulating the discharge of floodwater from Canyon Dam, five downstream gages are used as control points.

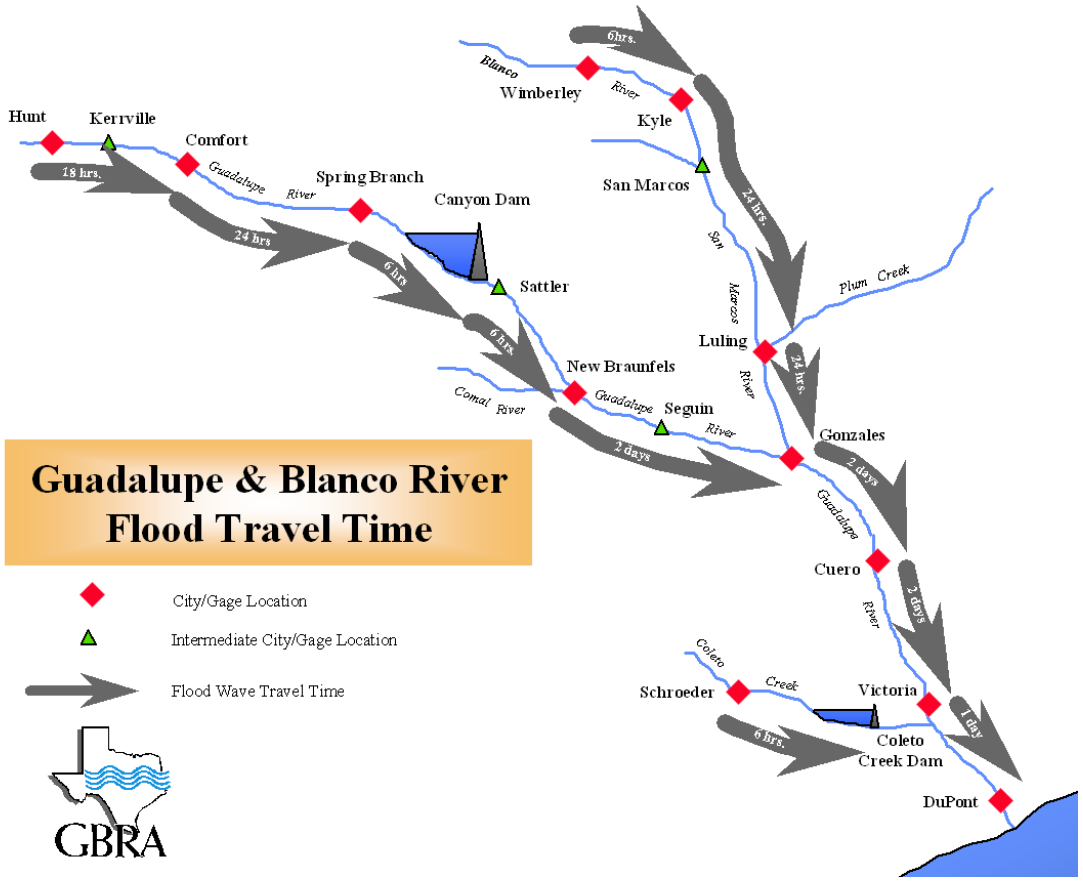

Figure 3. U.S.G.S. Stream Gages in the Guadalupe River Basin

Description of the Dam. Canyon Dam is a multipurpose lake used for flood control, water supply, hydropower, recreation, and fish and wildlife enhancement. The embankment consists of compacted earth fill 4,620 feet long, including a 210-foot dike. The outlet works consists of two 5-foot 8 inch by 10–foot slide gates that control the flow through a 10-foot diameter conduit. The slide gates are at the bottom of the intake structure located in the lake upstream from the embankment. The dam has an uncontrolled broad-crested spillway, 1,260 feet long. The lake capacity at different pool elevations is shown in Table 1.

Table 1. – Lake Elevation/ Capacity Information

Feature	Elevation (feet NGVD)	Reservoir Capacity (acre-feet)	(inches of runoff)
Top of Dam	974.0		
Maximum design water surface	969.1	1,129,300	14.86
100 Year Pool Elevation	946.0	776,000	10.21
Top of F-C pool and spillway crest	943.0	736,700	9.69
Top of conservation storage	909.0	382,000	5.03
Streambed at Dam	750.0	0	0.00

The Landmark Flood Event of 2002

Meteorology. A low-pressure system migrated west from Florida to Texas in late June 2002. This system stalled over South Central Texas. From 29 June to 6 July, tropical moisture was pulled inland from the Gulf of Mexico and the orographic lift provided by the Balcones Escarpment caused widespread heavy rainfall. Rains moved from south to north repeatedly causing tremendous rainfall accumulations on an area from southwest of San Antonio to the northern Hill Country. The low-pressure system moved north on 5 July, only to stall again in Central Texas. The system produced heavy rains in this area on 6 July. The low-pressure system finally moved northwest and weakened, ending the period of heavy rain in the Hill Country.

Between 8 July and 17 July, three more rounds of showers and thunderstorms occurred over the region. On 8 July, a weak tropical wave of low pressure moved inland along the Texas coast, bringing additional thunderstorms to much of South and Central Texas. On 12 July, a weak cold front moved into North Texas and stalled. Storms developed along this front and moved south, bringing additional showers to much of the Hill Country. Finally, a weak trough of low pressure moved across North Texas on 17 July, bringing another round of showers and thunderstorms over the region. Although the rains during the second period were not nearly as heavy as that of the first, runoff from these storms aggravated the ongoing flooding problems.

Rainfall. The main part of the storm event, between 29 June and 6 July, was concentrated in Kendall County and surrounding counties. The heaviest rainfall occurred between early morning and noon of 30 June. Rainfall intensities of 3 inches per hour were common. A volunteer weather observer in Waring, Texas recorded 14.05 inches of rainfall during a seven-hour period on the morning of 30 June. Waring is located in Kendall County on the Guadalupe River above Canyon Lake,

In the first week of July, a pattern of afternoon heating led to explosive evening and overnight thunderstorms. These evening thunderstorms also produced heavy rainfall. The observer in Waring reported 45.41 inches of rainfall during the seven-day period. Rainfall amounts recorded at National Weather Service stations located in the Canyon Lake watershed from 29 June to 6 July are listed in Table 2.

Table 2. - Precipitation (inches) recorded in the Canyon Lake watershed

NWS Station	29-30 June	1-6 July	Storm Total
Bankersmith	7.70	24.18	31.88
Camp Verde	3.00	31.17	34.17
Canyon Dam	5.60	14.23	19.83
Comfort 2	3.85	27.74	31.59
Hunt 10W	0.00	6.22	6.22
Ingram No. 2	0.26	12.01	12.27
Kendalia	3.63	22.03	25.66
Kerrville 3NNE	1.67	17.47	19.14
Northington	4.28	17.76	22.04
Sisterdale	2.65	28.10	30.75
* Waring	15.95	29.55	45.50

* Volunteer weather observer, not a NWS Station.

From NEXRAD, the estimated average rainfall over the Canyon Lake watershed was about 22 inches between 29 June and 6 July. A few areas near Center Point in Kerr County may have received over 50 inches.

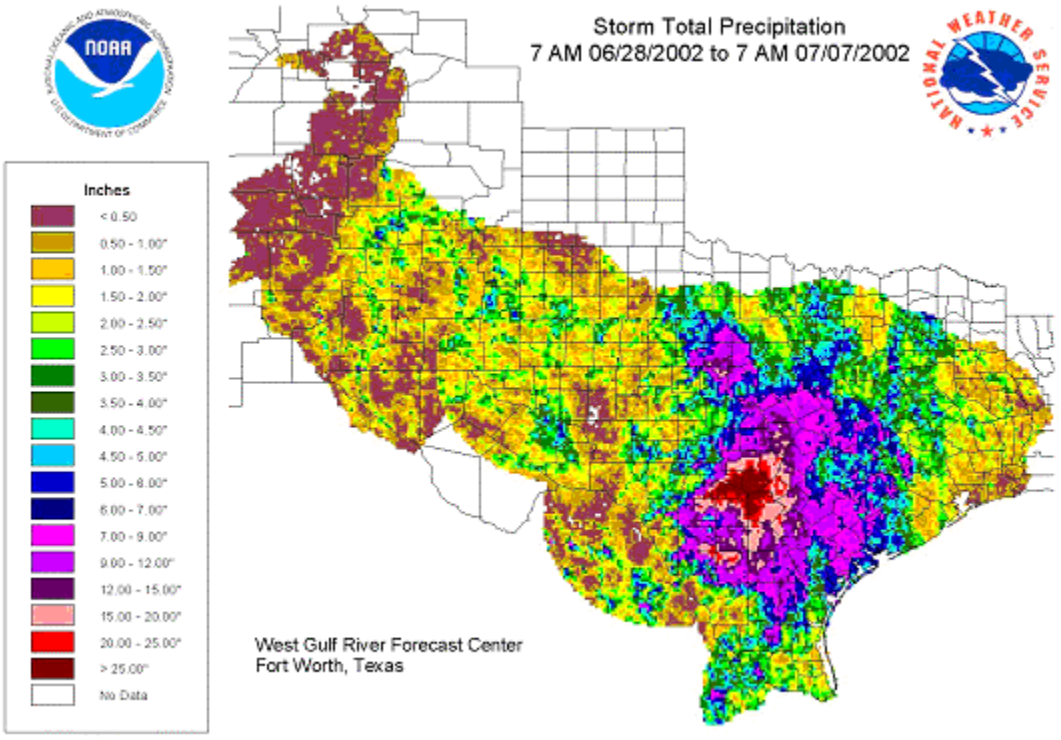

Figure 4. NEXRAD Rainfall Distribution Map.

Stream Flows. Torrential rains caused flooding of historic proportions on south Texas rivers. Major to record flooding occurred along portions of all the rivers in the Hill Country. Extensive damage occurred from flash flooding and headwater flooding in Wimberley on the Blanco River and in Kerrville on the Guadalupe River. Some communities were isolated by the flood waters in the upper Gaudalupe River for a day or more. Damage on the Guadalupe River below Canyon Dam was catastrophic in some locations.

Widespread rainfall across Kerr County and Kendall County sent five flood waves down the Guadalupe River into Canyon Lake in the first week of July. The highest inflow peak, of approximately 110,000 cfs, occurred on 5 July, see figure 5. During the first nine days in July, the total inflow into Canyon Lake was about 700,000 acre-feet of floodwater. The capacity of the flood pool is approximately 355,000 acre-feet.

Between 30 June and 31 July, the computed inflow totaled 872,000 acre-feet. This volume of water is equal to 11.5 inches of runoff, almost 50 percent of the total rainfall, which is enough to have more than filled the flood control pool twice. Due to saturation of the watershed, the Guadalupe River and its tributaries continued to run well above normal for several months.

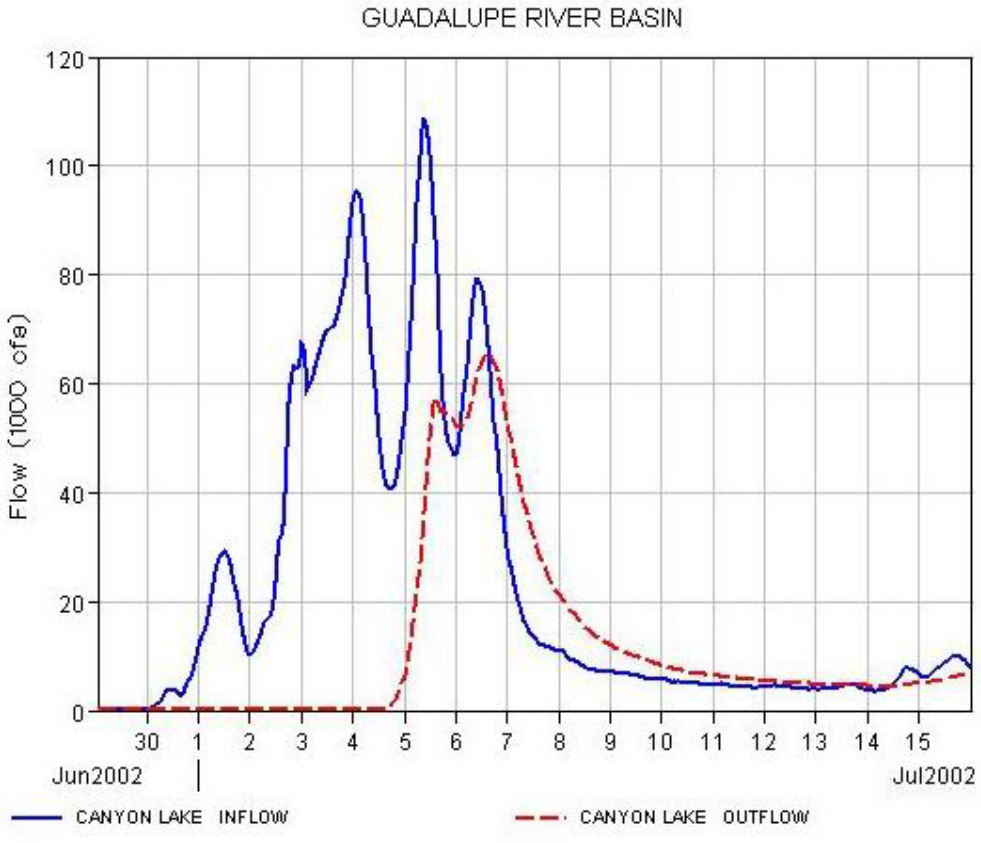

Figure 5. Canyon Lake - Inflow and Outflow Hydrographs.

Reservoir Operations. On 28 June, before the flooding began, Canyon Lake was at elevation 908.38 feet NGVD or 0.62 feet below the top of the conservation pool. The heavy rains and high inflow filled the lake to the top of the flood pool, elevation 943.0 feet NGVD, at 1530 hours on the Fourth of July. The waves of flood water continued to raise the lake level above the spillway crest. The lake peaked on 6 July at elevation 950.32 feet NGVD. At this elevation, the lake level was 7.32 feet above the spillway crest, having risen nearly 42 feet in just over a week, see figure 6. The maximum discharge over the spillway was about 66,800 cfs, whereas the control flow in the downstream channel at New Braunfels, Texas was 12,000 cfs.

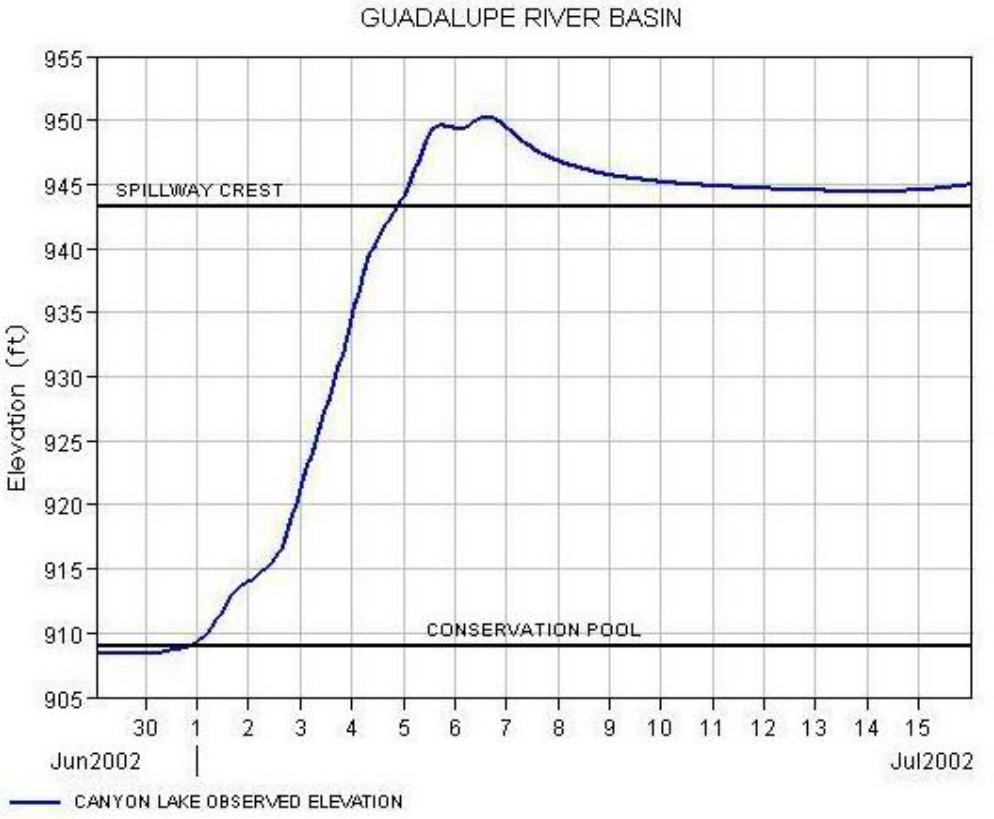

Figure 6. Reservoir Elevation vs. Time Curve.

On the evening of 5 July, the lake was forecast to rise several feet above the flood pool. Flood releases were initiated in an attempt to minimize the flow over the spillway. During the morning of 6 July, the releases had to be stopped due to surging in the stilling basin. The surging was caused by backwater from the spillway discharges. Debris and eroded material from the spillway had been carried into the river downstream creating a partial dam. Because of the blockage, flood releases could not be resumed until 10 August and only at a limited rate. Releases with the flood gates fully open were not made until 15 August. By then, the lake level had dropped below the spillway crest. It was not until 23 September that the lake level was lowered to the conservation pool, 909.0 feet NGVD

Shoreline Flooding. Consistent with national land acquisition policies at the time of Canyon Lake's design, the upper guide contour for government purchase of flood easements was established at 948.0 feet NGVD. This contour is five feet above the uncontrolled spillway crest. Yet it is not the highest possible level that may be experienced at Canyon Lake. This allows landowners who chose to build above the 948 contour a low, but not impossible, probability of being flooded by the lake operations. In July, with the effects of wave action, some landowners had 3 feet of water above the flowage easement. Fortunately, only a few minor complaints were filed concerning debris washing onto private property.

Summary. Because of the prevalence of Gulf moisture coupled with the orographic lift provided by the Balcones Escarpment, the Texas Hill County has recorded some of the most intense rainfall in the world. Canyon Lake has also experienced floods with higher peak inflows than the Flood of 2002, but what made this flood so unusual was the rapid succession of torrential thunderstorms over the same area. These thunderstorms produced five inflow hydrographs, all with large peaks. The volume of flood water generated by the combined storms is what made the Flood of 2002 a landmark event. Canyon Lake was constructed with a flood control pool large enough to contain the inflow from any three of the peaks, but could not control all five storms. The peak lake level, 950.32 feet NGVD, was estimated as having a 0.4 percent chance of being exceeded in any year (a 250-year frequency flood event).

The flood caused millions of dollars in damages along the Guadalupe River. However, an analysis of this event shows that without Canyon Dam, the flows in the Guadalupe River at New Braunfels would have crested three times (on 4, 5, and 6 July) at flow rates in excess of 80,000 cfs, with a maximum discharge in excess of 126,000 cfs. The observed peak at New Braunfels was about 70,000 cfs. In other words, the dam cut the maximum flow almost in half. Despite the overtopping of the spillway, Canyon Dam prevented an estimated 46.2 million dollars in damages during this event. Of the seven fatalities attributed to this flood event, none occurred in the Guadalupe River.

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